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COMPARATIVE ANALYSIS OF DISPERSION COMPENSATION USING ELECTRONIC DISPERSION COMPENSATION TECHNIQUES AT DIFFERENT BIT RATES USING SINGLE MODE FIBER

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ABSTRACT

The performance in the fiber optical communication is majorly limited by a phenomenon called dispersion which generally starts growing after 2Gbps data rate. The pulse gets widened as they travel down the fiber. This widening results in dispersion and other non-linearity. Pulses at the output overlap with the neighboring pulses and cause ISI (Inter-Symbol Interference). Distinct techniques are available to lessen the effect of dispersion like DCF, FBG, and electronic equalization. This paper focuses on reducing dispersion present in optical links by using adaptive equalization. To monitor and suppress the chromatic dispersion, simulations are performed using electronic equalizer at 20, 25 and 30Gbps. A comparison is made between the three data rates and found that maximum Q-Factor is attained at 20Gbps. Outcomes from the simulations show the overall improvement in the signal quality.

***KEYWORDS:** Dispersion, Chromatic Dispersion (CD), Dispersion Compensation, Optisystem 7.0, Electronic Dispersion Compensation (EDC), Fiber Bragg Grating, Dispersion Compensating Fiber (DCF), Bit Error Rate (BER) & Q-Factor*

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Original Article

1. INTRODUCTION

A standout amongst the most vital factors in optical fiber communication is compensation of dispersion. Optical fiber networks are the optical connections which have high information exchange rates and limit. In optical fiber communication networks information is transmitted in the form of light signals from transmitter part to receiver part. Generation of these light signals can be done either by using LEDs (Light Emitting Diode) or Lasers. In any case, similar to other communication networks, optical fiber communication system to faces certain issues like non-linear impacts, absorption, bending losses, dispersion etc. Out of the considerable number of issues looked by fiber optic communication intra modal or chromatic dispersion is regarded as the major crucial element which impacts the performance of a fiber optic communication [1-3].

1.1. Dispersion

There is a phenomenon in an optical communication system in which change in frequency causes the subsequent change in the propagation velocity of the wave. This change makes the waves to reach at the receiver section distinct intervals of time, thereby, causing the pulses to be widened and the phenomenon is known as chromatic dispersion.

1.2. Dispersion Compensation Methods

Because of the request for an information rate upper to 10 Gbps the detrimental impacts of dispersion and

nonlinearity have to be handled. Consequently, different remuneration procedures, based on the utilization of substituting fiber inverse dispersion, are actualized to enhance the execution and endurance of the system. These procedures are partitioned into two kinds: the utilization of Dispersion compensating fiber (DCF) and the utilization of Fiber Bragg Gratings (FBG). Other dispersion compensation method includes electronic dispersion compensation (EDC) and digital filters using digital signal processing.

1.2.1. Dispersion Compensating Fibers (DCF)

In a communication system utilizing both single mode fiber and dispersion compensating fiber, the positive dispersion of single mode fiber (SMF) is canceled out by the negative dispersion value of dispersion compensating fiber (DCF), thereby, making the overall dispersion equals to zero. This is the basic working principle of DCF. Three dispersion compensation schemes are available: Pre-compensation, Post compensation and symmetrical compensation [4-5].

1.2.2. Fiber Bragg Grating (FBG)

It is a reflective device that reflects a specific wavelength and passes all other wavelengths. Bragg's wavelength is a term used to define the reflected wavelength and it can be defined by the equation (1) given below:-

$$\lambda_B = 2n\Lambda \quad (1)$$

Where, λ_B = Bragg's wavelength

n = effective index

Λ = period of the grating

Utilizing Bragg grating for the compensation of dispersion is an effective approach as they have minimum insertion loss, less expensive and compatible with optical fiber. By changing both grating period and refractive index, the structure of FBG can be varied. The grating period can be either uniform or graded. Depending upon the grating style, FBG can be classified as uniform grating, chirped grating and superstructure grating [6-8].

1.2.3. Electronic Dispersion Compensation (EDC)

Electronic dispersion compensation technique uses electronics along with optics to compensate for the chromatic dispersion. There are numerous ways for compensation of dispersion by using EDC is present. It is the most effective technique for the compensation of the dispersion at the electrical unit of both transmitter and receiver. It is a type of technology that does not require any kind of changes in transmitting and receiving ends.

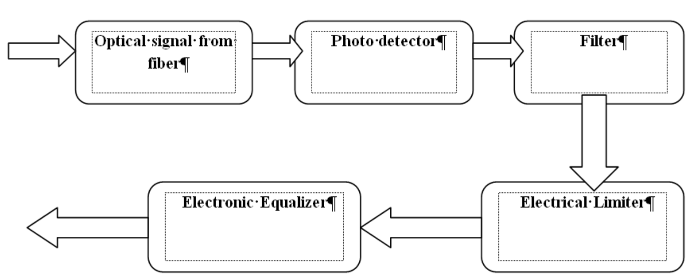


Figure 1: Showing the Block Diagram of an Electronic Equalizer

Addition of new gadgets in the network or any alteration in the network can be done effortlessly because electronic compensators have an adaptive capability. Still, these compensators offer demerits like circuits with electronic compensators have lesser speed in comparison with optical circuits. Distinct techniques are there for utilizing an electronic equalizer like feed-forward decision feedback equalizers (FFE-DFE), feed forward equalizers (FFE) and maximum likelihood sequence estimator (MLSE). The most common and easily implemented technique in EDC is using either decision feedback equalizer or feed forward equalizer or the blend of both. A simplified block diagram of an electronic equalizer is shown in Figure-1 given above.

Normally the mitigation is done in the optical field only that is before the detection by photo detector at the receiver. But in case of electronic dispersion compensation, utilization of electronics is done for fulfilling this purpose. Two distinct methodologies are there for the implementation of EDC that is as follows:-

- **Direct Detection Method**: This is used in the receiver section. This technique normally depends upon the tapped delay line equalizers where the input electrical signal is segmented and transmitted over distinct time delays then reconnected after amplification process. Some non-linear equalization methods like decision feedback equalizers (DFE) have a parameter called decision thresholds that are used to strengthen the extinct spectral information. These decision thresholds rely on the data of previous symbols.
- **Optical Heterodyne Detection Method**: This method is also used in receivers and has a quite high efficiency for EDC. This is because of the reason that the phase information is not lost. When an electronic filter having a suitable frequency response is applied to the intermediate frequency signal then this can precisely discard the impact of chromatic dispersion. Figure-2 is specifying a feed-forward equalizer with five taps.

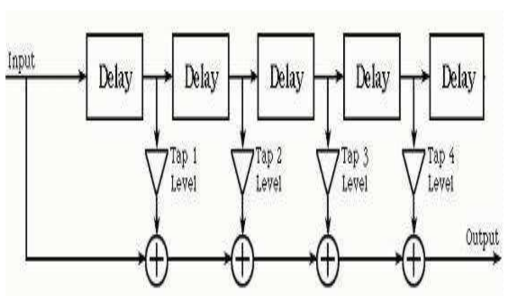


Figure 2: A Feed Forward Equalizer with Five Taps

The output of FFE is given by the equation (2) given below-

$$y(t) = \sum_{k=0}^{N-1} c_k . x(t - [k.\Delta t]) \quad (2)$$

Where, N = total no. of taps present in feed forward equalizer

x (t) = signal value at a time interval t

Another type of equalizer is shown in Figure-3 known as decision feedback equalizer [9-10].

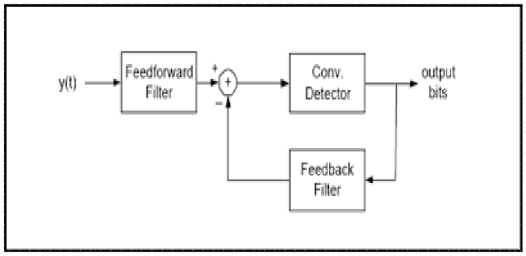


Figure 3: A Decision Feedback Equalizer Having Single Stage

Physical deterioration in the optical fiber, specifically, polarization impacts, fiber nonlinearities and chromatic dispersion, all the factors limits the information rate as well as transmission distance of the signal. Arrangements for moderating the impacts of these hindrances are conventionally based on strategies available in the optical field that means before the detection process. Optical compensators, in any case, depend on versatile optics and are generally ease back in reacting to the system debasement. These optical compensators are high priced and cumbersome gadgets. In order to compensate for the demerits exhibited by the optical compensators, electronic approaches have been used by the researchers to mitigate the effects of chromatic dispersion and other fiber non-linearity. Electrical approaches based on signal processing offer extraordinary adaptability in outline and can be coordinated inside the chipsets at the recipient, decreasing cumbersomeness. Likewise, they can conceivably work after the signal has been somewhat demultiplexed with the goal that electrical processing is done at a lesser rate, consequently generously bringing down the expenses [11].

This paper focuses on comparing the outcomes obtained before using electronic equalizers and after using electronic equalizers at a bit rate of 20, 25 and 30Gbps. Section-2 includes the simulation setup of the proposed model whereas the results and discussions are in Section-3. Section-4 covers the conclusion part of the paper.

SIMULATION SETUP

The motive of the simulations is to determine how the no. of forwarding tap coefficients, forward tap space, leakage factor and step size influence the performance of the equalizer. For carrying out the simulations, Optisystem 7.0 is used. The transmitter section of simulation model consists of a continuous laser to act as the light source, non-return to zero (NRZ) modulation scheme and Mach Zehnder modulator. On the other hand, receiver contains photo-detector pin diode along with electrical limiter and electronic equalizer for dispersion compensation. The whole setup is simulated for an SMF of 120 Km initially for 20 Gbps and then for 25 and 30 Gbps.

Table-1 contains the simulation parameters used whereas the simulation parameters for single-mode fiber are tabulated in Table-2. Further parameters used for the simulation of the electronic equalizer are shown in Table-3. Figure-4 is showing the simulation setup of the proposed model.

Table 1: Simulation Parameters

Parameters	Value
Bit Rate	20, 25 and 30 Gbps
Frequency	193.1 THz
Bandwidth	1 THz

Table 2: Simulation Parameters of SMF

Parameters	Value
Length	120 Km
Attenuation	0.2 db/Km
Dispersion	0.01 ps/nm/km
Differential group delay	3 ps/km

Table 3: Simulation Parameters of EDC

Parameters	Value
Step Size	0.3
Leakage Factor	1
Forward Tap Space	5
Forward Tap coefficients	3
Feedback Tap Coefficients	2

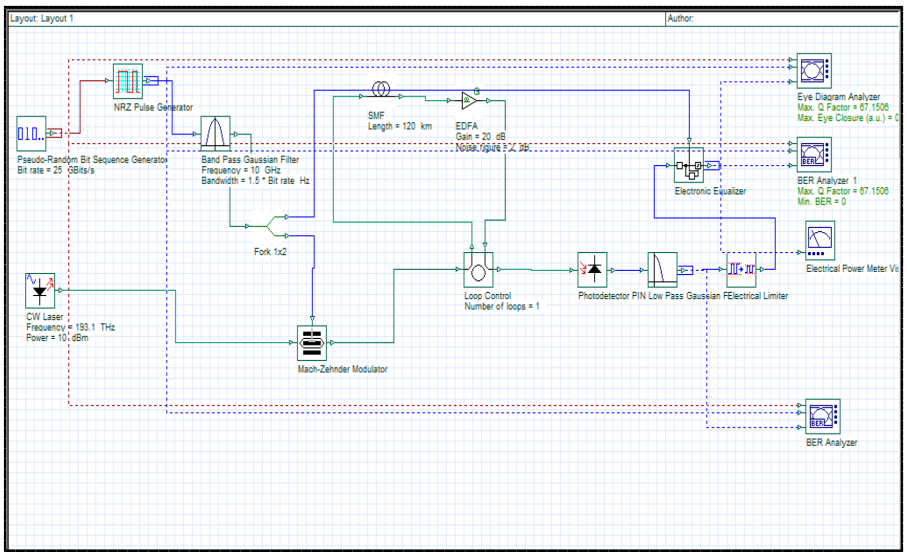
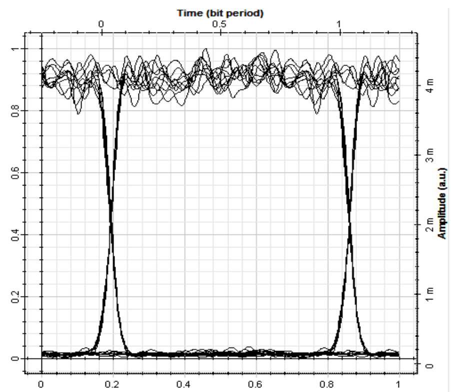


Figure 4: Simulation Setup of Model used for Dispersion Compensation by using EDC

RESULTS AND DISCUSSIONS

Since a large no. of variable parameters is available and there can be possibly large no. of combinations of simulations but it is not possible to simulate all the possible combinations within some specified time interval. The work in this paper focuses on changing only single parameter at a time and then examining its impacts on the transmitted signal. In order to analyze the capabilities of the equalizer, the outcomes are analyzed using eye diagrams. Outcomes are analyzed by changing input power ranging from 1 to 10dBm at distinct data rates of 20, 25 and 30 Gbps and then compared in terms of Q-factor. All the comparison has been done by comparing the output before using equalizer and after using an equalizer over a single mode fiber of 120Km at input powers ranging from 1-10dBm.



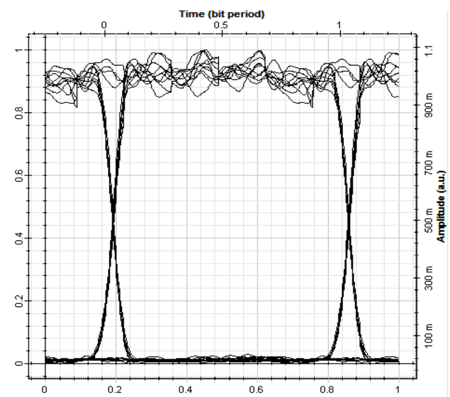
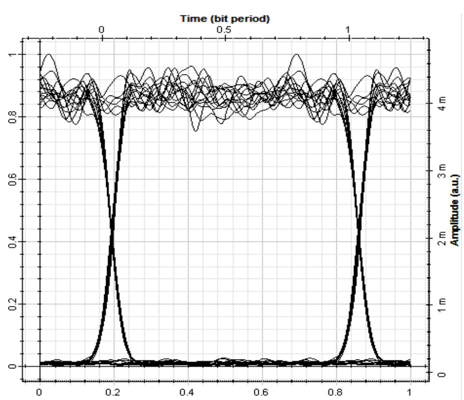


Figure 5: Eye Diagram at 20Gbps before Equalizer **Figure 6: Eye Diagram at 20Gbps after Equalizer**

Eye diagram for an input power of 10dBm before electronic equalizer is shown in Figure-5 whereas Figure-6 is showing the eye diagram at the same input power after the equalization of the signal by an electronic equalizer. This comparison is done at a bit rate of 20Gbps.



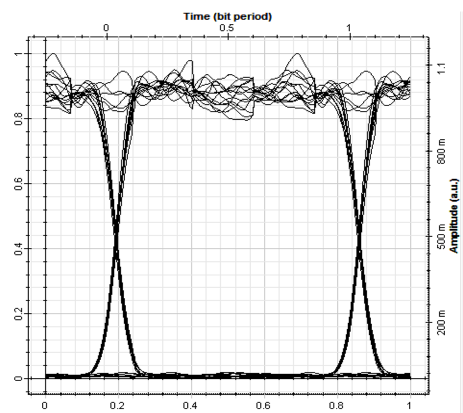


Figure 7: Eye Diagram at 25Gbps before Equalizer **Figure 8: Eye Diagram at 25Gbps after Equalizer**

A similar comparison of eye diagrams before and after equalizer is done for 25Gbps and is shown in Figure-7 and Figure-8, respectively.

Another simulation has been done by executing the transmitted signal at a bit rate of 30Gbps and then comparing the eye diagrams of the resulting pulses. The eye diagram of the signal before equalization is shown in Figure-9 whereas Figure-10 contains the eye diagram of a signal after equalization.

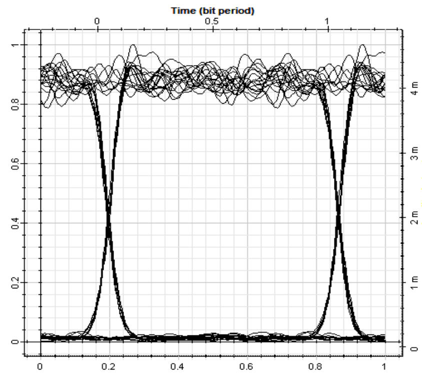


Figure 9: Eye Diagram at 30Gbps before Equalizer

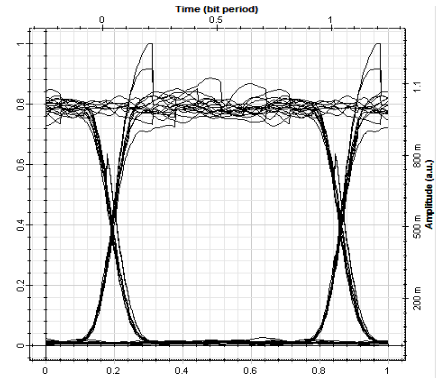


Figure 10: Eye Diagram at 30Gbps after Equalizer

After all the simulations, it is determined that without the equalizer, the output pulse carries dispersion with itself and hence, results in a distorted eye diagram. But when equalizers are used at the receiver side, the distortion reduces to some extent and received pulse exhibited better eye diagram than the previous one. Thus, making equalization techniques suitable for mitigating dispersion effects. Figure-11 is showing a comparison of the values of Q-Factors before equalization and after equalization at a data rate of 20Gbps.

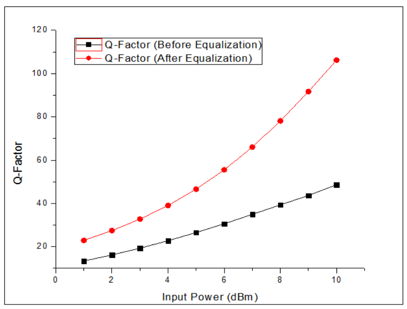


Figure 11: Input Power Vs Q-Factor plot at 20Gbps

Comparison of change in Q-Factor with respect to input power is also done at a transmission rate of 25Gbps before and after equalization. It is compared to find whether electronic equalization is capable of mitigating the effects of chromatic dispersion present in the transmitted signal. Figure-12 is showing the graph of input power with respect to Q-Factor before and after equalization. Figure-13 is showing the comparison graph of Q-Factor before and after equalization at a transmission rate of 30Gbps.

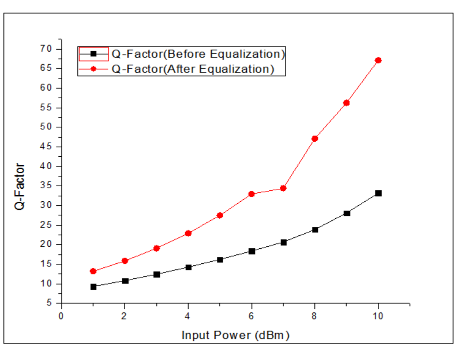


Figure 12: Input Power Vs Q-Factor Plot at 25Gbps

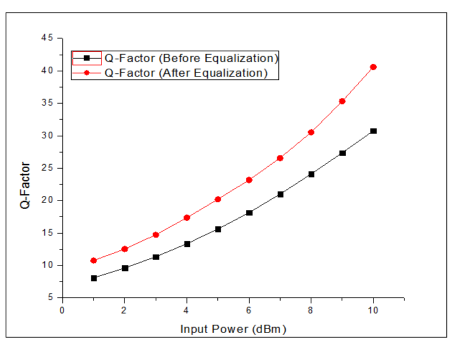


Figure 13: Input Power Vs Q-Factor Plot at 30Gbps

After the complete analysis of the Q-factor at distinct data rates of 20, 25 and 30Gbps before using the electronic equalizer and after using an equalizer, it is found that Q-Factor exhibited maximum value after the utilization of electronic equalizer at the receiver. Another comparison is made among the data rates of 20, 25 and 30Gbps. Figure-14 is showing this comparison of Q-Factors at distinct data rates It is observed that with the increase in the bit rate, the quality factor of the systems degrades and hence, a transmission rate of 20Gbps has maximum Q-Factor in comparison with other used bit rates at these simulation parameters.

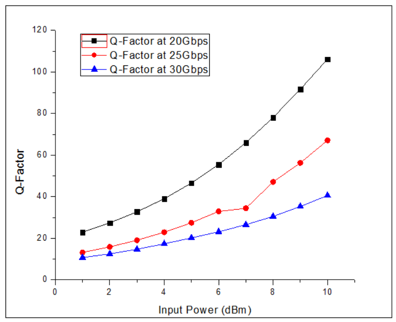


Figure 14: Comparison of Q-Factors at 20, 25 and 30Gbps

CONCLUSIONS

This paper concluded that electronic dispersion compensation is very effective and efficient way to compensate for the chromatic dispersion in a time-varying optical link. Analysis of Q-factors before equalization has been done and compared with the Q-Factor attained after utilizing electronic equalizers with parameters like step size equals to 0.3, leakage factor equals to 1, forward tap space equals to 5 and forward tap coefficients equals to 3. This analysis is done at bit rates of 20, 25 and 30Gbps. At all bit rates, it has been observed that Q-Factor has maximum value after equalization. The paper also concluded that 20Gbps has maximum quality factor among others at 120Km of single mode fiber.

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